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RECENT PROGRESS IN OUR KNOWLEDGE OF THE UNIVERSE[1]

IN his address at the dedication of the Yerkes Observatory in 1897, Simon Newcomb said, "If it be true that in nature nothing is great but man, in man nothing is great but mind, then may knowledge of the universe be regarded as the true measure of progress." Without discussing the validity of the premises which Newcomb himself casts in the conditional mood, let us boldly accept his conclusion and take time this evening to consider the progress we have made in the last thirty-five years by reviewing the increase of knowledge of the universe within that period. The time and the occasion are propitious for such an inquiry, for we are assembled to dedicate another great observatory; and this year, 1923, marks the 450th anniversary of the birth of Copernicus, whose book, "De Revolutionibus Orbium Coelestium," set the feet of men for the first time firmly on the road leading to knowledge of the universe and opened a new epoch in the development of the human mind.

The doctrine of Copernicus was more than epoch-making; it was revolutionary. The earth had been to men, in substance, the entire universe; the heavens a canopy drawn close about the earth; the sun, the moon, the planets and the stars merely greater or lesser lights set in that canopy for the comfort and delight of the dwellers upon the earth. Now they were asked to regard that earth as but a little planet, one of several revolving about a distant sun, and the stars, by implication, as vastly distant bodies that might rival with the sun in actual brilliance. No wonder that such heresy met with the most strenuous opposition; no wonder that only the boldest intellects became converts to it before Galileo, in 1609, turned the first small telescope upon the splendors of the sky and saw in the moons revolving about Jupiter a system, in miniature, resembling the one Copernicus had described.

I must resist the strong temptation to trace in detail the progress of astronomy through the centuries that followed. It is a brilliant story and one that has been told many times in prose and in verse. No one who has read it can have failed to note that advance in civilization closely paralleled the growth of man's knowledge of the universe, or to realize that this growing knowledge, by bringing man an ever-widening

[1] Address at the dedication of the Steward Observatory of the University of Arizona, April 16, 1923.

horizon, an ever greater freedom of thought, was a most potent factor in that advance.

Among the many conclusions that may be drawn from a thoughtful reading of this history, two are especially encouraging: First, that progress in astronomy has been continuous. From the days of Copernicus and Galileo the observations and generalizations made by any generation of astronomers have afforded the foundation upon which their successors could securely build. We have never had to go back and begin entirely anew, and even in our own times, observations of comets, of eclipses and of other objects and phenomena, made at dates preceding the invention of the telescope by many centuries, have been utilized to advance our knowledge. Secondly, that progress has been made at an ever accelerating velocity. At no period in history has the advance been so great as within the last few decades; and at no time has the promise for an increase of knowledge of the universe been as bright as it is to-day.

It was on June 1, 1888, almost precisely thirty-five years ago, that the newly completed Lick Observatory passed formally into the possession of the University of California and began its active work. Contrast the position of the astronomer at that date with his position to-day. The era of great telescopes was just opening; astronomical spectroscopy and photography were in their infancy; engineers were just beginning to develop practical methods of utilizing electricity as a motive power.

Since then four great observatories, besides the one at which we are gathered to-day, have been built on our own continent and several older ones have been rebuilt. If the advance in this respect has not been quite so great on other continents, still it has been remarkable everywhere and, in all, fully a score of powerful telescopes have been added to our equipment for exploring the universe. Particularly notable has been the development of the reflecting telescope since Keeler's work with the Crossley Reflector in 1898–1900 demonstrated the great efficiency of this type of instrument in many kinds of astronomical photography.

Coincident with the growth in the size and number of our telescopes has been the invention and improvement of auxiliary apparatus to utilize their great light-gathering powers in new ways and to increase the accuracy of our observations. The modern spectrograph, the spectro-heliograph, the precision photometers of various types, the bolometer, the pyrheliometer, the interferometer, the periodograph, have all come to use within the period I have named. Electric power and light are to-day as indispensable in our domes as in our most progressive industrial plants, and photographic observations have virtually displaced visual observations in all but a few lines of astronomical research.

Such greatly increased facilities, together with the remarkable progress in physics, in chemistry and in the methods of mathematical analysis, have put it within the power of astronomers to enter upon the study of a whole series of questions relating to the stars as organisms which earlier investigators had left practically untouched; not because they took no interest in them or failed to appreciate their importance, but simply because to them it seemed hopelessly beyond the power of the human mind to devise means of securing the data needed for their solution. It is in investigations along these lines that some of the most striking advances have recently been made, but the increase in our knowledge of stellar motions and of stellar distances is fully as great and as important.

The analysis of stellar radiations with the aid of our powerful spectrographs has enabled us not only to classify the stars according to the quality of their light but also to measure with high precision the velocities of the stars in the line of sight, and to discover, and even to compute the orbits of binary star systems that must forever remain invisible[2] to us, no matter how greatly our telescopes may be increased in size. We have made at least a beginning in the measurement of the temperatures, the masses, the densities, the angular and linear dimensions of the stars. We recognize "giant stars" and "dwarf stars"; stars intensely hot as compared with our sun and stars that are relatively cool; "young stars" just emerging, it may be, from an antecedent nebular stage, and "old stars," nearing the end of their history as luminous bodies. It would be easy to continue this catalogue until it filled many pages and to draw up one equally long of the achievements in researches relating to the structure of the stellar system. But it will be of greater interest, I think, to select one of them for more detailed presentation to illustrate modern methods and results.

Let us then consider a problem that has a history dating back to the days of Copernicus, the problem of determining the distances of the stars. The fact that the stars did not change their apparent position or direction from the earth in different seasons of the year, as they should do because of the earth's revolution about the sun, was regarded by the opponents of the Copernican doctrine as one of their strongest arguments against it and was the chief reason why so great an astronomer as Tycho Brahe rejected the doctrine. The proponents of the theory could only reply that the stars must be very far away, but all their efforts to find out how far did not yield a single stellar distance until nearly 300 years had elapsed. Their

[2] That is, no telescope can show both components of the closer spectroscopic binary stars, especially if they are unequal in their brightness. One component, or the unresolved image of the pair, must, of course, be visible.

work was by no means all in vain, for though it did not achieve the end for which it was undertaken it did lead to the discovery, by Bradley, of the phenomena of aberration and nutation and to the discovery, by Herschel, of the existence of the binary star systems. Moreover, it served to set a minimum limit to stellar distances, a limit that receded ever farther as instruments and observing methods improved. Even before the telescope was invented it was clear that the limit must be about 200 times the distance from the earth to the sun, for a lesser distance would cause displacements that could be detected by the unaided eye; by the middle of the 17th century it grew to 4000, early in the 18th century, to 20,000 or 30,000 times that distance. By the 19th century astronomers had become convinced that the nearest stars must be at least 200,000 times as far away as the sun, or, in technical terms, that the largest stellar parallax could not much exceed a second of arc. This term, parallax, is a convenient one and I shall use it in what follows. It signifies the angle at the star between lines drawn from the star to the sun and to the earth, respectively; the farther away the star, the smaller the angle. Having this angle, we readily determine the distance, for in the triangle, earth, sun, star, we know one side, namely, the distance from the earth to the sun, and all the angles.

Finally, in the years 1838–39, three astronomers, working in different places, with instruments of different types, announced almost simultaneously the parallaxes of three different stars; Bessel, the parallax of 61 *Cygni,* measured with the heliometer, Henderson, the parallax of Alpha *Centaur* determined from meridian circle observations, Struve, the parallax of Alpha *Lyrae,* from micrometer measures with his equatorial telescope. Success being thus achieved, after nearly three centuries of unavailing endeavor, it might have been anticipated that knowledge of stellar distances would grow rapidly, particularly in view of the constant improvement in instruments and the ever better understanding of the requirements of the problem. Actually, however, progress was slow. By 1880, it is fair to say, we had approximate values of the distance of but a score of stars; by 1900, of some threescore, only, and the prospects for rapid or great increase in number by visual observations were by no means encouraging.

But by this time methods of photographing the stars and of measuring their positions on the resulting plates had been developed to such a degree that it seemed feasible to attack the extremely difficult problem by the photographic method. Pritchard, at Oxford, indeed, had taken a large number of photographs for this purpose as early as the years 1887–1889, and these had led to the parallaxes of 28 stars. His work deserves high praise, even though it has since been found that his results are affected by systematic errors of considerable size. Early in the present century, however, when Kapteyn had definitely enunciated the "reasonable precautions" that must be taken by the observer, first at the telescope and then at the measuring microscope; when Turner and others had developed the exceedingly accurate modern methods of plate measurements; when Schlesinger had shown how to eliminate in large degree the very troublesome "guiding error"; then it became possible to enter hopefully upon a greatly extended program of parallax work.

In the meantime astronomers had been learning the lesson so thoroughly drilled into the heads of baseball and football men by their coaches—that good teamwork is fully as essential to the winning of games as brilliant individual play. Cooperation in astronomical research was by no means a novelty in the latter half of the 19th century, but in the 20th century it has become one of the distinctive features of our work. The photographic determination of parallaxes affords an excellent illustration. While each individual guards and preserves his right of initiative, astronomers at seven observatories, six in America and one in England, have formulated a cooperative program that ensures the elimination of useless duplication of labor and as great a degree of homogeneity in the results as differences in instrumental equipment and observing conditions will permit. Now they are engaged in that most generous form of rivalry in which each one gives all the others the benefit of any improvement in methods of manipulation or of computation he has devised, applauds every success the others achieve, and strives for even greater success himself. It is, therefore, not surprising, though extremely gratifying, that by 1915 we had the parallaxes of at least 200 stars and that now the number is well past the thousand mark and is growing at the rate of perhaps 150 to 200 a year.

At the same time we must face the fact that the number of stars whose parallax can be measured directly with the best of modern telescopes and with the most scrupulous attention to every detail of observation and measurement is strictly limited and pitiably small in comparison with the total number even of the brighter telescopic stars. In 1915, Sir Frank Dyson considered 0″.02 the smallest parallax that could be measured with any reasonable degree of accuracy. Translated into other terms, this means that if a star is more than ten million times as far away from us as the sun is, we can hardly hope to measure its distance. To-day, eight years later, this may perhaps be regarded as a rather conservative statement, but even to-day no responsible astronomer would care to set a limit very much greater. It is

true that by any terrestrial standard of distance 10 million times that to the sun is enormous, and that no human intelligence can comprehend it. Yet we have every reason to believe that the stars within a sphere of space of this radius do not number more than 20,000 to 25,000 (half of them probably too faint for photographic parallax measurements), whereas the number in our stellar universe is of the order of 1,000 million.

We now open a new chapter of our story. There is an obvious relation between the apparent brightness of a luminous object, its intrinsic or true brightness and its distance from the observer. Two lights may appear to be of equal brightness, because they really are equally bright and are at the same distance from us, or because the one of greater intrinsic brightness is farther away, the law of variation of brightness with changing distance being the well-known law of the inverse square; double the distance and the light is diminished to one fourth its former brightness; halve it and the light is increased fourfold.

Thanks to the efficiency of modern photometers and to the extensive and skillfully executed researches which have led to an accurate scale of visual and of photographic magnitudes, we can now determine with all desired accuracy the apparent brightness or magnitude of any star down to the faintest ones revealed by our telescopes. If then, by some means, we can also determine its *intrinsic* brightness or its "absolute magnitude" (the magnitude it would have at a definite distance from us) it is clear that its distance becomes known. But how is it possible to know anything about the actual luminosity of a star until we know how far away it is? As recently as the opening year of the present century the problem might well have been declared insoluble. Fifteen years later the answer was found in the correlation between the relative intensities of certain spectral lines and the intrinsic brightness of stars of the same spectral class.

This is not the place for a detailed explanation. It must suffice to say that we have ascertained from laboratory experiments and from solar observations that the character and intensity of certain spectral lines are strongly affected by changes in the physical conditions in the light source. Now, "if two stars which have closely the same type of spectrum differ greatly in luminosity it is probable that they also differ greatly in size, mass and in the depth of the atmospheres surrounding them. Accordingly, we might hope to find in these stars certain variations in the intensity and character of such spectrum lines as are peculiarly sensitive to the physical conditions of the gases in which they find their origin, in spite of the close correspondence of the two spectra in general." Adams, whom I have been quoting, was not the first to search for such lines, but it was he who first succeeded in using them to determine stellar parallax. His paper describing the method was published in 1916; five years later he and his collaborators were able to publish a list of the parallaxes of 1646 stars; and these values are of the same order of accuracy as the best photographic ones.

The method has not as yet been successfully applied to stars of all spectral classes, but we may look forward with confidence to its further extension. Thousands of stellar spectrograms, taken for other purposes, are also available at several of our great observatories, and it is certain that many of these will be utilized for parallax determinations by this new method. Great, therefore, as has been the recent advance in knowledge of the distances of individual stars, the prospects are bright for still more rapid progress in the coming years. For there is, practically, almost no limit to the number of the stars whose distances can be measured by the spectroscopic method. To determine uniquely the absolute magnitude of a star we need only spectrograms on a scale sufficiently large to record accurately the relative intensities of the spectrum lines, and as our instrumental equipment grows more powerful we may hope to get such spectrograms of ever fainter stars.

I have treated this problem of the determination of stellar distances at considerable length not only because of its intrinsic importance in our studies of the structure of the universe, but because it illustrates admirably many of the characteristics of modern astronomical research, and, in particular, the fact that advance in any one line is so closely correlated with and dependent upon advance in others which are seemingly entirely unrelated to it. Nothing, for example, could have been farther from the thoughts of those who were investigating the behavior of the spectra of gases under different physical conditions than that their results would be applied to the determination of the distances of the stars.

Let me now continue my story by reviewing more rapidly some of its other developments. The determination of the position of stars upon the surface of the celestial sphere is one of the oldest forms of astronomical observation, dating back to the days of Hipparchus. The first catalogue giving star places of sufficient accuracy for comparing with modern meridian observations is Bradley's, about the middle of the 18th century. Since then, by the patient, skilful labor of scores of able astronomers an enormous mass of data has been accumulated and made available for analysis by statistical methods. Comparison of the positions of stars observed at different dates shows that these are changing; slowly, indeed, but in many instances rapidly enough to make the change measurably great within a few years or decades or a century

or two. Herschel utilized the scanty knowledge of such motions—proper motions, we call them—available in his day to prove that they were due in part to the actual motion through space of the solar system itself; and with the insight, and, may I add, the good fortune of genius, he was able to estimate the direction of this motion with amazing accuracy.

It is obvious that the motion of the sun through space provides the astronomer with an ever-lengthening base line from the extremities of which he can observe the positions of the stars and hence their "parallactic" displacement. These observations do not lead to the distance of any particular star, because the star's own motion is a factor in its displacement; but, assuming as a first approximation that the stars are moving quite at random; that, in the average, in any given area of the sky as many stars are moving north as south, east as west, towards us as away from us, they do lead to a knowledge of the *average* parallactic displacement of the entire group and hence to the *average* distance of the stars in it. Within the past twenty-five years men like Kapteyn, Campbell, Boss, Dyson, Charlier, to name but five of an illustrious company, have been engaged in a series of brilliant researches on the motions of the stars. Campbell, it is true, has been concerned entirely with the motions of the stars in the line of sight, as determined with the spectrograph, but it will appear immediately that his measures have the greatest significance in the questions I am discussing. Remarkable, indeed, are some of the results obtained. Thus Boss demonstrated that a number of stars apparently unrelated and widely scattered in the region of the constellation *Taurus* are really moving together through space along practically parallel lines. The spectrograph supplied the radial velocities of a few of the brighter members of the group, and the combination of the data on simple geometrical principles led directly to an accurate knowledge of the distances of every star in the group. Several such "moving clusters" are now recognized and are the subjects of fruitful study.

Still more striking was the announcement by Kapteyn, in 1904, that the stars as a whole are divided into two great streams moving towards vertices at two diametrically opposite points in the plane of the Milky Way. The stars of the two streams are thoroughly intermingled and members of either stream are to be found in every part of the sky, being distinguishable only by their motions. This conclusion has been abundantly verified by later investigations and stands as one of the most important contributions yet made to our knowledge of the stellar system.

Again, Campbell and Boss, quite independently and almost simultaneously, announced that the stars of different spectral classes are moving through space with different velocities.[3] The stars of Class B, the blue white stars, at one end of the series of spectral classes, have the smallest average velocity; and the velocity increases, class by class, as we pass from the white stars through the yellow stars on to the red stars of Class M at the other end of the series. Each investigator gave values for the average velocity, and also for the average parallax of the stars in each group; Campbell from an analysis of the radial velocities of the stars after making correction for the sun's motion through space, the velocity of which his researches measured for the first time, Boss from a similar analysis of the proper motions; and the two sets of figures were in excellent accord.

Carrying his work still farther, Kapteyn was able to calculate the approximate *average parallax* or distance of stars of every order of magnitude and of every spectral class. Thus, these diverse researches on the distances of individual stars, on star positions and proper motions, on radial velocities, and on the quality of lines in stellar spectra are all made to focus upon the great fundamental problem of the form and structure of the stellar universe.

I have by no means enumerated all the investigations which bear upon this great problem. I have said nothing, for example, of the binary stars. I might show how they lead us to a knowledge of stellar masses and densities; and, conversely, since we find the range in mass to be relatively small, how we can compute the "hypothetical parallaxes" of the visual binaries (as Jackson and Furner have recently done for more than 550 pairs) by assuming an average value for the mass. Or I might ask you to consider the variable stars, and especially the Cepheid variables, and show how Miss Leavitt's discovery that in the Cepheids in the Smaller Magellanic Cloud a definite numerical relation exists between the magnitude of the star and its period, that is, the length of one complete cycle of light variation, enabled Hertzsprung to estimate the distance of the Cloud itself and put into the hands of Shapley a new gigantic "yard-stick" with which he has measured the distances of the globular star clusters and the dimensions of the stellar system.

The precise length of this yard-stick depends upon the absolute magnitude of the nearer Cepheid variables, and it may well be that further observations will modify to some degree the value adopted by Shapley; the *validity of its use* rests upon the assumption that the relation between magnitude and

[3] Kapteyn's independent investigations led him almost simultaneously to the same general conclusions. More recent investigations indicate that this apparent correlation between velocity and spectral class may prove to be, physically, a correlation between velocity and mass, the less massive stars having the greater space velocity.

period which holds for the Cepheids in the Magellanic Cloud is independent of the star's environment and characterizes these variables wherever they appear, whether in space comparatively near us or in the most distant star cluster. The assumption has been challenged and it is not impossible that it may prove to be invalid; but it is supported by so much corroborative evidence that it commands ever more respect and credence.

A similar remark applies to many other generalizations as to the structure and dimensions of the universe. *Quantitatively,* they are admittedly approximations which are to be corrected and improved as additional data of observation are accumulated. They also involve *assumptions,* some of which can not be submitted to direct tests, but which are adjudged valid because they seem to be in harmony with accepted physical laws and give results which agree with observation. Some of them, no doubt, will have to be modified; some may have to be abandoned entirely. But it is certainly an inspiring fact that, imperfect and limited as our knowledge is, it is yet sufficient to have enabled Kapteyn, in the last paper published before his death last year, to formulate—with hesitation and some misgivings, it is true, but yet with confidence in the principles involved—"a tentative theory of the dynamical organization of the stellar universe."

The researches which I have been reviewing relate chiefly to one of the two fundamental problems of astronomy; the other is that of stellar evolution. This is distinctly a problem of our own times, one that could not be attacked until spectroscopy and photography had been successfully applied in stellar observations, until modern methods of solar research had been developed, and physicists and chemists had given us a better insight into the properties of matter and especially of matter in the gaseous state.

Observationally, stellar spectra provide the first and by far the most important data for the study of stellar evolution, and for the vast accumulation of such data now available astronomers gratefully acknowledge that they are indebted most of all to the late Professor Pickering and his colleagues at the Harvard College Observatory. The monumental "Henry Draper Catalogue of Stellar Spectra," of which seven volumes have already been distributed, contains the classified spectra of more than 200,000 stars. The first remarkable fact to be noticed is that fully 99 per cent. of all the stars whose spectra have been examined fall into one or the other of only six great groups, designated by the arbitrary letters B, A, F, G, K and M. The next is that these groups grade into each other in such a way as to form a continuous linear series, the color deepening from white through yellow and orange to red as we pass from B to M. The classification is on an empirical basis depending simply upon the characteristics of the spectral lines; but the continuity and particularly the linearity of the series is strong evidence, in Russell's words, "that the principal differences in stellar spectra, however they may originate, arise in the main from the variations in a single physical condition in the stellar atmosphere." All astronomers now agree that this dominant physical condition is temperature, a conclusion that has been abundantly confirmed. We have even been able to measure stellar temperatures directly by the use of extremely sensitive thermocouples in conjunction with some of our great reflecting telescopes, and thus have definite knowledge that the intensely white Class B stars are the hottest, the red Class M stars the coolest in our series. These facts point to a genetic or evolutionary relationship between the stars of successive spectral classes; the question is as to the direction in which the evolution proceeds.

Within the past decade data for the discussion of this question and the related question of the status of matter antecedent to the stellar stage have been offered in such abundance, in such variety and in such rapid succession as fairly to bewilder the conservative mind. The astronomer has been applying his telescope to the measurement of the radial velocities of the nebulae and has found not only that the planetary nebulae are moving at speeds greater than those of the most rapidly moving stars (on the average), but that the velocities of the spirals are so much greater still as to be of an entirely different order. He has found that the planetaries, with but few apparent exceptions, are rotating on their axes; he is adducing ever stronger evidence that the matter in the arms of spiral nebulae is moving outward along the curves of the arms. He has shown that the great diffuse gaseous nebulae have such low velocities as to be practically at rest with respect to the stellar system; and, further, that diffuse nebulous matter capable of obstructing rather than of radiating light is extraordinarily abundant. He has studied the distribution in the sky and especially with reference to the galactic plane, of stars of different spectral characteristics, of binary stars, of variable stars, of nebulae of the different types, and has found, for example, that the red stars of Class M, whether bright or faint, are distributed over the sky almost at random and that they exhibit no relationship of position to the diffuse nebulae, whereas the stars of Class B, among others, are strongly concentrated towards the plane of the Milky Way and show a marked apparent affinity for the diffuse nebulae.

While observatories and astronomers in all parts of the world have been making effective and valuable contributions in such researches, it is a matter of legitimate pride that the astronomers in our own coun-

try, using our great modern telescopes, and particularly those in our Pacific area, have been among the leaders in nearly all of them.

All this material and far more, including the ever-growing volume of data on the visual and spectroscopic binary stars, on variable stars and on solar phenomena, the astronomer is placing at the disposal of the student of stellar evolution; and it is only fair to say that the latter is availing himself of it all and of all the progress made by physicists and chemists in their researches on the properties of matter, eagerly and effectively. It would be interesting, did time permit, to follow in detail the development of evolutionary theory during the past thirty-five years, but, passing scores of valuable contributions by Schwarzschild, Eddington, Jeans and many others without a reference, I can only take time to present most summarily and imperfectly the theory which now, in its general features, commends itself strongly to the majority of astronomers. It was first proposed by Lockyer, so far as its fundamental principle goes, but it has been so expanded and enriched and in many features so radically modified by Russell and so brilliantly presented and defended by him that we commonly refer to it as Russell's theory.

Briefly, the theory assumes that in the beginning of their stellar stage all stars are of Class M. They are then bodies of gas of extraordinarily low density and of low temperature and surface brightness. As they contract they grow ever hotter and pass through the successive spectral classes towards B, but only the more massive stars can generate heat enough to reach the white-hot state required to produce spectra of Class B; the others reach their critical density at spectral Class A, F, G or even K. After this critical point in their contraction is reached the stars begin to fall off in temperature and in luminosity and gradually pass through the spectral classes in the reverse order until they again become red stars of Class M before they finally sink to invisibility. The stars on the ascending branch are, in the terminology introduced by Hertzsprung, chiefly "giants," those on the descending branch chiefly "dwarfs," the terms "giant" and "dwarf" referring to luminosity rather than to mass.

On this theory the very bright red stars of Class M must be giants of enormous volume to compensate for their low surface brightness. On the basis of observational and theoretical data Russell and Eddington, independently, calculated the "hypothetical" diameters of some of these stars, and it is one of the most cogent arguments in favor of the theory that the recent interferometer measures of Betelgeuse and of Antares at the Mount Wilson Observatory, which constitute one of the most brilliant achievements of modern observational astronomy, are in excellent agreement with these predicted values.

Innumerable difficulties remain to be overcome, innumerable questions to be answered; but in the investigation of stellar evolution as in the investigation of the form and dimensions of the stellar universe, we may at least feel that our feet are set firmly on the road to fuller knowledge.

What of the future? Prediction would be worse than vain. Who, thirty-five years ago, could foresee the discovery of star-streaming, of the correlation of stellar velocity with spectral class, of the applicability of stellar spectra to the measurement of stellar distances? One thing, and only one is certain. Never have the opportunity and the need for good work, well-planned, skilfully executed work, in observational astronomy been as great as they are to-day. In his able address to the American Astronomical Society, Schlesinger recently presented the urgent need of extensive observations of star positions to provide further data on proper motions. It would not be at all difficult to show at least equal need for measures of the radial velocities of stars and nebulae; for measures of stellar distances; for photographic investigations of nebulae and of star-clusters; for qualitative studies of stellar and nebular spectra; in brief, for extensive additions to every form of observational data on the motions and radiations of the nebulae and of the stars.

To secure these additions to our knowledge we must have observatories equipped with powerful modern telescopes and their accessory instruments, and we must have more trained observers. For material equipment and support we must look to a generous public and we shall not look in vain if we, who are learning a little about this great universe of ours, tell what we learn and make it part of the common knowledge of our time. For trained observers we must turn, first of all, to the students of our universities. I count it, therefore, a matter for special congratulation that this new observatory, the gift of a private citizen, a public spirited woman, equipped with the first powerful telescope whose *optical* as well as mechanical parts were all made in our own country, located in a most favorable climate, and directed by an able astronomer of wide experience, is so closely associated with a vigorous and rapidly developing university. It will be its high privilege not only to make significant contributions to our knowledge of the universe—knowledge that promotes the progress of which it is itself the true measure—but to inspire eager youth who, when we of the older generation one by one lay down the torch, will

> Take . . . the splendor, carry it out of sight
> Into the great new age (we) must not know
> Into the great new realm (we) must not tread.

ROBERT G. AITKEN

LICK OBSERVATORY

CHARLES PROTEUS STEINMETZ[1]

THE whole world, through its orators and writers, has expressed so beautifully and so well its appreciation of Charles Proteus Steinmetz that if I attempted to express what is in my heart, it would be but to repeat what has already been said much better by others. However, as his devoted friend and intimate associate for one third of a century, as one who recognized his great talents when he was unknown, and surrounded him with a favorable environment for the development of his genius, I regard it as a privilege to publicly endorse all that has been said of his usefulness, his commanding genius, his inspiring personality. This cheerful, patient, kindly spirit, this zealous student of nature and lover of humanity was your friend and my friend.

I have been asked to speak of his scientific attainments and their meaning to the world. To do this properly would be to cover much of the history of the electrical industry during the past 30 years. I must confine myself to sketching such features as seem of most importanec and possibly of greatest interest.

Thirty years ago I first met Steinmetz. The occasion was as follows: The General Electric Company had been recently formed by the union of the Edison Company and the Thomson-Houston Company, which brought into one enterprise the results of the work of Edison, Elihu Thomson and many other early pioneers in the fields of arc and incandescent lighting, electric traction and industrial motor application.

Rudolph Eichmeyer, of Yonkers, had developed some interesting designs for electric traction purposes, and certain novel and economical forms of windings for armatures of electrical machines. I was then in charge of the manufacturing and engineering of our company and my views were sought as to the desirability of acquiring Eichmeyer's work. I remember giving hearty approval, with the understanding that we should thereby secure the services for our company of a young engineer named Steinmetz. I had read articles by him which impressed me with his originality and intellectual power, and believed that he would prove a valuable addition to our engineering force.

I shall never forget our first meeting at Eichmeyer's workshop in Yonkers. I was startled, and somewhat disappointed by the strange sight of a small, frail body surmounted by a large head, with long hair hanging to the shoulders, clothed in an old cardigan jacket, cigar in mouth, sitting crosslegged on a laboratory work table. My disappointment was but momentary and completely disappeared the moment he began to talk. I instantly felt the strange power of his piercing but kindly eyes, and as he continued, his enthusiasm, his earnestness, his clear conceptions and marvelous grasp of engineering problems convinced me that we had made a great find. It needed no prophetic insight to realize that here was a great man, one who spoke with the authority of accurate and profound knowledge and one who, if given the opportunity, was destined to render great service to our industry.

I was delighted when, without a moment's hesitation, he accepted my suggestion that he come with us.

Steinmetz had already made his first important contribution to electrical science in investigations of magnetism, and especially in formulating and determining the laws governing the losses in iron subjected to varying magnetic induction. He showed that the hysteresis varied as the 1.6 power of the density of magnetic flux. This made possible for the first time the exact predetermination of the so-called iron losses in the armatures of electric motors and generators and in the transformers and other electrical apparatus employing iron. As a result, the quality of our electrical machinery was improved, and the weight and costs reduced. It is difficult at this date to realize the fundamental importance of this one contribution to the orderly and definite progress of the electrical industry.

During the first decade of the commercial application of electricity to light and power which may be said to cover the period between 1880 and 1890, direct current only was used. This was the basis of the Edison system, the Thomson-Houston arc system, the Vanderpool and Sprague railway motor systems. The laws governing the flow of direct current were simple and easily understood, and could be treated by mathematics of the most elementary character.

About the time Steinmetz came with the General Electric Company in 1893, the use of alternating current for lighting, power and other purposes was just beginning to be of demonstrated commercial value. Advance in the commercial use of alternating current was hindered by the extreme difficulty of understanding the technical nature of its action and of the various phenomena connected therewith. The engineer who had been working with direct current found it difficult to understand and therefore to correctly design alternating current apparatus. While the problems of the direct current apparatus and electric circuits could be treated by the simplest mathematics such as ordinary arithmetic, the alternating current, involving such phenomena as reactance, capacity, leading and lagging currents, phase displacements, etc., could apparently only be solved by higher mathematics involving the use of calculus methods which were not generally familiar to the engineers of those days. Even skilled mathematicians familiar with such

[1] Address delivered at the Memorial Meeting in Schenectady, October 31, 1923.

methods made slow and difficult progress in the solution of the problems which arose daily.

Steinmetz took hold of this situation with characteristic energy, and soon brought order out of chaos. He abolished the mystery and obscurity surrounding A. C. apparatus and soon taught our engineers how to design such machines with as much ease and certainty as those employing the old familiar direct current.

He had already made the discovery that alternating current problems could be attacked and solved with success by the use of what was known as complex quantities. By the use of this system he not only was able to solve these problems himself, but to teach our engineers to do the same work by methods almost as simple as ordinary arithmetic and algebra. Steinmetz himself regarded this as one of his greatest contributions and called it the development of the "symbolic method of alternating current calculations." This method was found to be so powerful, accurate and rapid that its use was not confined to the engineers of our company, but rapidly spread throughout the world. He preferred to use this mathematical method in the treatment of all problems of alternating current engineering which arose and advocated its use before the American Society of Electrical Engineers in numerous papers, and embodied it in the text-books of which he was author.

Not only did the adoption of these mathematical methods open the door to many to do useful design work who otherwise could not have done so, but it enormously increased the speed with which definite and accurate calculations and designs could be made. It furnished the engineer with a powerful tool which multiplied his power with just as much certainty as the machine tool improves and multiplies the usefulness of the ordinary workman.

It was fortunate indeed for our company and for the electrical industry that Steinmetz became associated with us at the critical time when the alternating current development had just started. It is not too much to say that his genius and creative ability, not only in his own personal work, but in advocating and obtaining the general use of a simple mathematical system for treatment of A. C. problems, were largely responsible for the rapid progress made in the commercial introduction of alternating current apparatus.

Steinmetz's practical inventions literally cover the entire field of electrical applications: Generators, motors, transformers, lightning arresters, lighting, heating and electrochemical operations. Of these many inventions, which were set forth in some 200 patents, perhaps the most important are the induction regulator, the method of place traisformation, as from two phase to three phase, and the metallic electrode arc lamp.

His experimental work in arc lighting led to the production of the magnetite arc. The practical advantage of this type of lamp is found in the extreme length of time which the metallic electrode will burn without recharging—these electrodes burning 200 hours contrasted with a life of 70 hours in the carbon arc used before his time. The efficiency also of this type of lamp, especially in small units of illumination, was of great commercial value.

He devoted much time to the development of the mercury arc and by his masterly methods did much to improve this interesting and important type of illumination. These and many other of his inventions have found permanent and extensive use in the industry.

During the last ten years, when alternating current power transmission lines of great length, carrying large amounts of energy, have spread all over the country, to use his own words, "an old enemy became more and more formidable—lightning," and for many years the great problem which pertained to the successful development of electrical engineering was that of protection from lightning. Before this could be undertaken with reasonable hope of success we must know a great deal more about lightning and centered phenomena. This led to the investigation of transient phenomena. It was soon found that while lightning might have been the criminal which started the trouble in the electrical system, the damage and destruction was not done by lightning, but by the electric machine power back of the circuit which was let loose and got out of control by the disturbance initiated by lightning. He goes on to say that the study of the phenomena produced by lightning effects could in general be grouped under the name of "transients" because, unlike the direct and alternating currents which flow continuously, these disturbances last a limited time only. The study of this problem led him to produce his famous "lightning" generator of which so much has been told in the public press. In the hands of Steinmetz and his assistants such progress has been made that the nature of the phenomenon has been so elucidated that as a result it is possible to proceed with confidence in the further development of the large high-powered transmission systems, making possible Steinmetz's vision that the day was rapidly approaching when the electrical engineer would supply the world's requirements of energy over transmission lines which would cover the country with a network similar to that of the railways, the one taking care of the distribution and supply of energy, and the other carrying the materials.

Steinmetz was an ardent believer in the value of education. He not only found time to aid the educational work of Schenectady, but became president of the national association of corporation schools and

lecturer at Union College. In a masterly address, upon retiring as President of the American Institute of Electrical Engineers in 1902, he stated that all future progress in science and engineering depends upon the young generation, and to insure unbroken advance it is of preeminent importance that the coming generation enters the field properly fitted for the work.

His personal example, his spoken words and his writings have had a powerful and beneficial influence upon the development of education, especially technical education in this country.

That I have not overstated the value of Steinmetz's work in this early period is indicated by the message of an eminent electrical engineer, Professor Harris J. Ryan, president of the American Institute of Electrical Engineers, who says: "Through a period of years Dr. Steinmetz stood almost alone as the one electrical engineer in the world capable of defining and solving the many perplexing problems encountered for the understanding and improvement of the transformer, induction motor, alternator and polyphase high voltage system, the modern fundamental implements of the electrical engineer."

That the value of Steinmetz's services were not limited to the General Electric organization is well known, but it is satisfactory to have the testimony to that effect by the president of a great electrical manufacturing company who states: "He has been such an outstanding figure in engineering work for so many years and is so well known to the public that his death will be a great loss not only to the profession but to people generally."

One of our largest customers offers the following tribute: "He was untiring in his devotion to the development of the electrical industry and in his passing the industry has suffered an irreparable loss."

From far Japan comes the following comprehensive and beautiful encomium: "He spent his life serving humanity."

A representative of the greatest electrical manufacturing company in Germany offers the following tribute: "It will always remain one of the highest merits of your company that he found here the congenial environment and support necessary for a genius like his to develop to the fullest benefit of mankind."

Professor Elihu Thomson, one of our country's greatest scientists and electrical engineers, a man whom all the world delights to honor, sends this tribute: "In the death of Dr. Steinmetz the science of electrical engineering has lost a great leader, whose talents were most exceptional. Nearly a third of a century has passed since he displayed a faculty amounting to genius in the application of mathematical methods to the solution of difficult problems in electrical work, and throughout the subsequent period this special work of his has been followed up unremittingly. His numerous books and papers, his lectures and discussions will in themselves constitute an imperishable monument for all time. His long connection with the General Electric Company gave him the needed opportunity to put into extensive practice his ideas, and the resulting value to the industry itself can not be measured or estimated. The whole science of transient phenomena in electric circuits is virtually his, and he had the qualities of the patient teacher and expositor to those seeking information as students or listeners to his discourses. Only those who have followed his career, so full and so fruitful, can know the vacancy created by his absence from among us."

I must now bring to a close this inadequate sketch of the contributions of this remarkable man to the development of the electrical science and industry. During his short life he rendered services of the most conspicuous character and inestimable value.

He was the author of many original scientific papers and of a large number of electrical books which have been the accepted standards in colleges, laboratories and workshops everywhere.

He was a prolific inventor, a skilled mathematician, a trained engineer and an inspiring teacher. Our generation has produced men who have equalled or excelled him in some one of these fields, but no one has arisen who, to such a superlative degree, combined the qualities of inventor, mathematician, engineer and teacher.

He possessed a marvelous insight into scientific phenomena and unequalled ability to explain in simple language the most difficult and abstruse problems.

Countless electrical engineers now occupying positions of great importance in our company and elsewhere in the world gladly give testimony of their debt to him.

He was patient, sympathetic, cheerful and ever willing to share his great gifts with all those who sought his counsel.

He loved children and they loved him. A neighbor and his wife were mourning his loss in the presence of their children, when the father exclaimed with deep emotion, "and he was my friend." His little son of seven years looked up from his play and said: "He was my friend, too, daddy."

We, his fellow citizens, friends and associates, join the great world in mourning his loss, but may our grief be tempered by the memory of his great achievements which make his name the synonym of high service to humanity.

E. W. RICE, JR.

HONORARY CHAIRMAN OF THE BOARD,
GENERAL ELECTRIC COMPANY

SCIENTIFIC EVENTS

THE NORTHWEST SCIENTIFIC ASSOCIATION

THE Northwest Scientific Association was organized at a meeting held at 4:00 P. M., April 6, 1923, in the Lewis and Clark High School, Spokane, immediately following the regular sessions of the Inland Empire Teachers Association. According to the newly adopted constitution, the object of the association "shall be the promotion of scientific research and the diffusion of scientific knowledge."

This new association opens its doors to any one interested in the various lines of scientific endeavor in botany, bacteriology, zoology, agriculture, mathematics, astronomy, physics, chemistry, geology and geography, anthropology, ethnology, psychology, education, social and economic sciences, historical and philological science, engineering, medical science and manufactures and commerce. It is the expectation that the membership will be drawn very largely from the Pacific Northwest, including the states of Oregon, Idaho, Montana and Washington and the Canadian provinces of British Columbia, Alberta and Saskatchewan.

Forty-five charter members were enrolled at the organization meeting, which was brought about very largely through the efforts of Professor Thomas Large, of the Lewis and Clark High School, Spokane. Opportunity has been offered for any others interested in science to become charter members and as a result the original group has been increased to 134 on June 30, when the list of charter members was closed. It is confidently expected that the new organization will become a real dynamic force in the northwest.

One or more regular meetings will be held each year for the presentation and discussion of papers. As the membership grows, it is expected that special divisions or sections will be organized, but this will depend entirely upon the membership and the interest manifested. This association is being welcomed by scientific workers of the Pacific northwest, as it will bring together groups that have been unable to attend the scientific meetings east of the Rockies or the distant Pacific Coast meetings.

It is not the idea of the association to interfere with any existing scientific societies, clubs or organizations, but it is the hope that the association may bring about an affiliation of the various local organizations. It is hoped that local groups or clubs will be organized in the various universities, colleges, normal schools, high schools or communities which will promote acquaintance and friendship among scientific workers and stimulate a more active interest in science and scientific research.

The officers of the association are as follows:

President, Dean M. F. Angell, University of Idaho, Moscow, Idaho.

Vice-president, Dr. Curtis Merriman, Cheney Normal School, Cheney, Washington.

Secretary, Dr. F. D. Heald, State College of Washington, Pullman, Washington.

Treasurer, Professor E. B. Harris, Spokane University, Spokane, Washington.

Councilors, Dr. Morton T. Elrod, University of Montana, Missoula, Montana; Dr. A. L. Melander, State College of Washington, Pullman, Washington; Dr. H. S. Brode, Whitman College, Walla Walla, Washington.

F. D. HEALD,
Secretary

THE PENNSYLVANIA STATE COLLEGE BRANCH

THE local branch of the American Association for the Advancement of Science at The Pennsylvania State College held a symposium on "Fuel utilization" on Monday, October 29. The meeting was held in two sections, one from 4:30 P. M. to 6:00 P. M. and from 7:30 P. M. to 10:00 P. M. with intermission with dinner for the members and guests at six o'clock. The program was as follows:

4:30 P. M.

Introduction and discussion of combustion principles: DEAN E. A. HOLBROOK, of the School of Mines.

Sources and types of natural fuels: PROFESSOR C. A. BONINE, of the Department of Geology.

Analysis of the cost of a ton of coal: PROFESSOR W. R. CHEDSEY, of the Department of Mining.

Modified and substitute fuels: DR. D. F. MCFARLAND, of the Department of Metallurgy.

6:00 P. M.

Intermission and dinner at the University Club.

7:30 P. M. (immediately following dinner).

Heating the small house: PROFESSOR F. G. HECHLER, of the Department of Mechanical Engineering.

The comfort zone in house heating: PROFESSOR A. J. WOOD, of the Department of Mechanical Engineering.

The meeting was open to members and their wives and to members of the teaching and experimental staffs of the School of Engineering and the School of Mines. There was a good attendance, since the application of the principles of Fuel Utilization to house heating is a timely topic and one of considerable interest to householders.

THE AMERICAN SOCIETY OF NATURALISTS

THE forty-first annual meeting of the American Society of Naturalists will be held in Cincinnati, Ohio, on Saturday, December 29, 1923, in affiliation with the American Association for the Advancement of

Science, and in cooperation with the principal other biological societies. The meeting is under the auspices of the University of Cincinnati in whose building the sessions will be held.

Several papers on important biological subjects may be added to the morning program that is being arranged. Papers are not limited to any specific phase of the biological sciences, but should be of as general interest as may be. They should also be short. Members desiring to present papers should submit titles to the secretary before November 15, and should state the probable time required, and whether blackboard, chart space, lantern, etc., are needed.

A symposium on the general subject of "Morphogenesis" is being arranged for the afternoon, in cooperation with the Botanical Society of America and the American Society of Zoologists. Participation in the symposiums by Professors Harrison, Buller, Harper and others is assured.

The annual dinner, with the address of the president, Professor R. A. Emerson, will be given on Saturday evening.

Headquarters of the society will be at the Hotel Gibson.

Blank forms for the nomination of candidates for membership in the society may be obtained from the secretary. Attention is called to the rule that nominations must be in the hands of the executive committee at least a year before being acted upon. Accordingly, nominations to be voted upon in 1924 must reach the secretary before the close of the meeting of 1923.

A. FRANKLIN SHULL,
Secretary

UNIVERSITY OF MICHIGAN,
ANN ARBOR, MICHIGAN

THE MATHEMATICAL ASSOCIATION OF AMERICA

THE eighth annual meeting of the Mathematical Association of America will be held at the University of Cincinnati on Thursday and Friday, December 27–28, in affiliation with the American Association for the Advancement of Science, and the Chicago Section of the American Mathematical Society. On Friday afternoon there will be a joint session of the organizations, and on Friday evening there will be the usual joint dinner. At the first session of the association on Thursday afternoon, President Carmichael will deliver his presidential retiring address on the "Present state of the difference calculus and its prospect for the future." Other papers for this session and for the session on Friday morning will be announced in the full program which will be sent to members as usual early in December. At the joint session on Friday afternoon there will be addresses by Professor G. A. Miller as retiring chairman of Section A of the American Association for the Advancement of Science on "American mathematics during three quarters of a century," by Professor A. B. Coble as retiring chairman of the Chicago Section "On the equation of the eighth degree," and by Professor L. E. Dickson on "Algebras and their arithmetics," by invitation of the Mathematical Association and of the Chicago Section.

Because of the Cincinnati meeting of the American Association for the Advancement of Science, our members will enjoy a reduced rate for these meetings, amounting to a fare and a half. This will thus afford an unusual opportunity for our members throughout the Middle West, as well as from points farther west and east.

The Hotel Sinton will be the headquarters for the members of the Mathematical Association.

W. D. CAIRNS,
Secretary

THE THORNDIKE MEMORIAL LABORATORY OF THE BOSTON CITY HOSPITAL

THE Thorndike Memorial Laboratory of the Boston City Hospital was formally opened on November 15. The dedication exercises were presided over by Dr. Henry S. Rowen, representing the board of trustees, and addresses were made by His Honor, James M. Curley, Mayor of Boston; Dr. William J. Mayo, of Rochester, Minnesota, and Dr. Townsend W. Thorndike, of Boston.

The new building was made possible by the bequest of the late Mr. George L. Thorndike, a merchant of Boston, who left his residuary estate to the trustees of the Boston City Hospital for the erection of a building which was to be equipped and supported by the city. The basement and ground floor are devoted to the X-ray department and the three upper floors form a division for clinical research. The second floor is a ward for nineteen beds, the majority being in single or double rooms, while the third and fourth floors contain laboratories for research in chemistry, physiology and biology.

The Boston City Hospital has at present about 1,200 beds and from this large number of patients selected groups will be taken to the Thorndike Memorial Laboratory for special investigation. The members of the laboratory staff will be in part men who are on salary and are devoting themselves largely or entirely to research work, and in part volunteer assistants who give approximately half time to research. The members of the staff at present are: Francis W. Peabody, director; Joseph T. Wearn, Thomas R. Buckman, Robert N, Nye, Henry Jackson, Jr., G. O. Broun, Percy B. Davidson, Elmer H. Heath, Donald S. King, Gulli Lindh Muller.

The budget of the laboratory, both salaries and running expenses, is borne by the City of Boston. Its establishment thus constitutes a striking instance of the recognition of the value of research to a general hosiptal by the trustees of a municipal institution.

SCIENTIFIC NOTES AND NEWS

THE Nobel prize for medicine for 1922 has been divided between Professor Archibald V. Hill, professor of physiology in University College, London, and Professor Otto Meyerhof, professor of physiology in the University at Kiel, for work on muscular contraction.

DR. J. J. R. MCLEOD and Dr. F. G. Banting, between whom the Nobel prize for medicine for 1923 was divided, have each again divided the prize, so that Dr. J. B. Collip, professor in the University of Alberta, and Dr. Best, collaborators in the work, will each receive $10,000.

DR. WILLIAM W. KEEN will receive an honorary doctor's degree from the University of Paris on November 24, at the opening exercises at the Sorbonne amphitheater.

A SPECIAL congregation of the University of Manchester was held on November 10, when the Earl of Crawford, K.T., was installed as chancellor and honorary degrees were conferred on a number of distinguished persons, including Dr. J. G. Adami, F.R.S., vice-chancellor of the University of Liverpool; Sir Arthur Keith, F.R.S., conservator of the museum of the Royal College of Surgeons of England, and Sir J. G. Frazer, F.R.S., author of *The Golden Bough*.

THE gold medal of the Royal Society of Medicine was presented to Dr. F. Gowland Hopkins, F.R.S., Sir William Dunn professor of biochemistry in the University of Cambridge, when on October 30 Professor Hopkins delivered an address on "Stimulants of growth."

MR. ROSITA FORBES, the English explorer, was presented with the gold medal of the French Geographical Society on November 7 after she had delivered a lecture on her experiences. Mrs. Forbes recently returned from a trip to Morocco.

DR. CHARLES H. MAYO, Rochester, Minn., was elected president of the American College of Surgeons at the annual meeting held in Chicago on October 25.

SIR ARTHUR CHANCE was elected president of the Royal Academy of Medicine of Ireland on October 12.

BOHUSLAV BRAUNER, professor of chemistry in the Bohemian University, Prague, has been elected an honorary foreign member of the French Chemical Society.

THE *Journal* of the American Medical Association writes: "The tribute to Professor C. Eijkman on the twenty-fifth anniversary of his professorship at Utrecht was an imposing ceremony. An album was presented with signatures of the Netherlands friends and another is on the way from the Dutch East Indies, and thirteen brief addresses were made by representatives of the government and scientific societies, including the Society of American Bacteriologists. The microbiologists cited a long list of Eijkman's innovations, such as his test for fermentation and his study of thermolabile substances which check bacterial growth. A fund was endowed in his name to provide a medal for achievement in tropical medicine."

AT the annual meeting of the Royal Society of Edinburgh, on October 22, the following council and office bearers were elected: *President,* Professor Frederick O. Bower. *Vice-presidents,* Major-General W. B. Bannerman, Dr. W. A. Tait, Principal J. C. Irvine, Lord Salvesen, Professor J. H. Ashworth and Professor T. H. Beare. *General Secretary,* Professor R. A. Sampson. *Secretaries to Ordinary Meetings,* Dr. A. Lauder and Professor W. Wright Smith. *Treasurer,* Dr. J. Currie. *Curator of Library Museum,* Dr. A. Crichton Mitchell. *Councillors,* Professor H. S. Allen, Sir Robert Greig, Dr. J. Ritchie, Professors E. M. Wedderburn, T. H. Bryce, J. Y. Simpson, D'Arcy Thomson, Sir James Walker, E. T. Whittaker and H. Briggs, W. L. Calderwood and Professor T. J. Jehu.

THE College of Physicians of Philadelphia has awarded the Alvarenga prize of $300 to Dr. Edward P. Heller, Kansas City, Mo., for his essay entitled: "Treatise on Echinococcus Disease." The next award of the prize will be made on July 14, 1924, provided an essay deemed by the committee of award worthy of the prize shall have been offered.

AUGUST MERZ, of Heller and Merz, has been elected chairman of the dyestuffs section of the Synthetic Organic Chemical Manufacturers Association, New York City, to fill the vacancy caused by the death of Fred E. Singer.

DR. W. LEE LEWIS, head of the department of chemistry of Northwestern University, has been appointed director of scientific research for the Institute of American Meat Packers with headquarters in Chicago. The purpose of this division of the Institute's activities is to make a study of the research problems presented by the packing industry. The trustees of Northwestern University have granted Dr. Lewis a leave of absence from February 1, 1924, for a period of one year in order to allow him to devote his time to the organization of this work. This arrangement includes the continuation of the direction of research work under Dr. Lewis on carbohydrates

and organic arsenic compounds now being carried on at the university. During Dr. Lewis's absence Professor Frank C. Whitmore will serve as acting chairman of the department.

OTTO M. RAU, power specialist of Philadelphia, has been appointed in a consulting capacity to the staff of the Giant Power Survey for Pennsylvania.

AT the inauguration of Dr. Herbert Spencer Hadley as chancellor of Washington University, which occurred on November 10, the American Association for the Advancement of Science was officially represented by Dr. George T. Moore, director of the Missouri Botanical Garden.

DR. J. WALTER FEWKES, chief of the bureau of American ethnology of the Smithsonian Institution, left on November 5 for Florida, where for several months he will investigate Indian mounds and other relics of the pre-Columbian Indians.

DR. FREDERICK L. HOFFMAN, of Wellesley Hills, consulting statistician of the Prudential Insurance Company of America, sailed on November 10 to attend the Belgian cancer congress which will be held in Brussels from November 18 to 20. Dr. Hoffman will make an address on "Cancer and civilization." He expects to return to the United States early in December.

PAUL F. CLARK, professor of medical bacteriology in the University of Wisconsin, has recently returned from a semester's leave of absence spent in travel and study in Europe. After serving as a delegate at the Pasteur Centenary in Paris, Professor Clark worked in the laboratory of the Pasteur Institute in Brussels, under Professor Jules Bordet, and in the Molteno Institute of Parasitology in Cambridge, under Professor George H. F. Nuttall. Later in the summer he visited the laboratories of the more important London hospitals and of the University of Oxford.

J. R. LOVEJOY, a vice-president and director of the General Electric Company, who sailed from Vancouver, B. C., for Japan soon after the catastrophe, to assist in relief and reconstruction, will remain in that country for some time to promote rehabilitation, particularly of electrical projects. Mr. Lovejoy has for many years been interested in the foreign activities of the General Electric Company.

DR. JAMES N. HART, dean of University of Maine, and for the past thirty years head of the department of mathematics, has been granted leave of absence by the trustees.

D. R. HOAGLAND, associate professor of plant nutrition of the University of California, and W. Metcalf, associate professor of forestry, have been given a year's sabbatical leave of absence for foreign travel and study.

THE anniversary discourse of the New York Academy of Medicine was delivered on November 1 by Dr. William S. Thayer, of Baltimore, his subject being "Studies on acute bacterial endocarditis."

MR. GERARD SWOPE, of the General Electric Company, gave the first Aldred lecture at the Massachusetts Institute of Technology on November 9. His subject was "The engineer's place in society."

DR. S. C. LIND, chief chemist of the Bureau of Mines, addressed the Chemical Club at Princeton University on November 8 on "Are gaseous ions chemically active?"

MR. F. E. MATTHES, of the U. S. Geological Survey, gave a lecture on November 3 before the Brooklyn Institute of Arts and Sciences on "The cliffs and waterfalls of the Yosemite Valley."

THE Stamford Chemical Society, of Stamford, Conn., was addressed at their October meeting by Dr. R. B. Moore, formerly of the Bureau of Mines, who spoke on the development of the production of helium during the war and at the present time.

THE second John M. Dodson lecture of the Alumni Association of Rush Medical College will be delivered by Professor Arthur Biedl, University of Prague, in the amphitheater of Rush Medical College on November 23 at 4:30 P. M. The subject will be "The nervous and endocrine control of the functions of the alimentary tract."

DR. WILLIAM EDWARD GALLIE, of Toronto, has been appointed Hunterian professor and lecturer at the Royal College of Surgeons, London, England, for April, 1924. His subject will be "Living sutures."

DR. ARTHUR DUNN PITCHER, professor of mathematics of Adelbert College, Western Reserve University, since 1915, died on October 5.

JOHN T. HEDRICK, S.J., died at St. Andrews-on-Hudson, near Poughkeepsie, N. Y., on October 24 in his seventy-first year. He had been astronomer, and then director, at the Georgetown College Observatory for many years. Failing health obliged him to retire to St. Andrews.

GEORGE WHARTON JAMES, of Pasadena, California, known as an explorer and ethnologist, died on November 8, aged sixty-five years, at St. Helena, California.

DR. A. A. RAMBAUT, F.R.S., formerly professor of astronomy in the University of Dublin and royal astronomer of Ireland, the Radcliffe Observer at the University of Oxford, died on November 4, aged sixty-four years.

THE death is announced of Dr. P. Friedländer, privat-dozent for organic chemistry and technical organic technology in the Technical Hochschule at Darmstadt. Dr. Friedländer is well known for his investigations on the chemistry of dyestuffs and for his work "Fortschritte der Teerfarbenfabrikation," which appeared in twelve volumes.

DR. KARL FLUGGE, emeritus professor of hygiene at Berlin, has died at the age of seventy-six years. The Flügge foundation was organized in his honor on his seventy-fifth birthday.

Nature states that a movement is on foot to commemorate the late Sir Isaac Bayley Balfour. An area of 50 acres in Glenbranter Forest, Argyllshire, where the plants raised at the Botanic Garden, Edinburgh, can be cultivated under suitable conditions and where trials may be made in the rearing of newly imported conifers and other trees, has been secured for the purpose. It is proposed that the area shall be called the Bayley Balfour Arboretum or Garden, and that the memorial shall take the form of a rest-house for the use of visitors. Subscriptions towards the memorial are solicited. They should be sent to the honorary secretary and treasurer, Mr. J. Sutherland, 25 Drumsheugh Gardens, Edinburgh.

THE one hundred and twenty-third regular meeting of the American Physical Society will be held at the Ryerson Physical Laboratory of the University of Chicago, on November 30 and December 1. Other meetings are scheduled to take place as follows: December 27–29, Cincinnati, Annual Meeting; February 23, 1924, New York; April 25–26, 1924, Washington; Pacific Coast Section—place not yet determined.

ARRANGEMENTS for the Washington Meeting of the American Chemical Society have been planned definitely for the week of April 21, 1924. The council meeting will be on Monday of that week, a general meeting on Tuesday, and the following three mornings will be devoted to divisional meetings and the afternoons to sightseeing at the technical institutions in the city.

THE American Institute of Chemical Engineers is completing plans for its sixteenth annual meeting to be held in Washington, December 5 to 8.

THE Chicago Section of the American Chemical Society has originated a plan for this year whereby each section will be responsible for one monthly issue of *The Chemical Bulletin*. The Wisconsin Section will publish the November issue in cooperation with the Milwaukee, Wisconsin, Minnesota, Iowa, Ames, Louisville, Nebraska, Kansas City, Illinois, Purdue and Arkansas sections. *The Chemical Bulletin* reaches some 2,500 chemists.

DR. CARL WILHELM L. CHARLIER, professor of astronomy at the University of Lund, and director of the Lund Observatory in Sweden, will lecture at the University of California during the summer of 1924. During the Intersession, Professor Charlier will offer a course entitled, "The Motion of the Stars." In the Summer Session, which opens June 23, he will conduct a course on "The Distribution of the Stars."

THE Salters' Institute of Industrial Chemistry has awarded sixty-four grants in aid to chemical assistants, occupied in factory or other laboratories in or near London, to facilitate their further studies.

UNIVERSITY AND EDUCATIONAL NOTES

MR. MILTON S. HERSHEY, chocolate manufacturer, has placed his entire fortune, estimated at sixty million dollars, in trust for the orphanage and industrial school founded by him at Hershey, near Harrisburg, Pa., in 1909.

THE General Electric Company of New York has given $5,000 to the Cavendish Laboratory of the University of Cambridge, of which Sir Ernest Rutherford is the director, to promote investigations, and the British Thomson-Houston Company £250 for a similar purpose.

THE University of London has accepted a gift of £10,000 to found a chair of otology and the donor, Geoffrey E. Duveen, intends to allocate a further £15,000 to University College Hospital to provide for the treatment of the deaf.

MR. GEORGE BLUMENTHAL, of New York, has made a gift of 250,000 francs to the University of Paris, to be used in the best interests of science and art.

DR. LEWIS HILL WEED has been named by the trustees of Johns Hopkins University as dean of the medical school. Dr. Weed, who is professor of anatomy, succeeds Dr. J. Whitridge Williams, who recently resigned to devote his time to the women's clinic of Johns Hopkins Hospital, of which he is director.

DEAN DAN T. GRAY, of the Alabama Polytechnic Institute, has been appointed Dean of the College of Agriculture and director of the Agricultural Experiment Station in the University of Arkansas. It is expected that Dean Gray will assume his new duties about January 1.

DR. CARL R. FELLERS has been appointed associate professor in charge of the newly established department of food preservation, University of Washington.

Dr. Fellers was formerly associated with the U. S. Bureau of Chemistry and with the National Canners Association.

NORMAN W. KRASE has resigned from the Fixed Nitrogen Research Laboratory to accept an instructorship at Yale University in the department of chemical engineering.

THREE new instructors have been appointed in the geology department of the University of Michigan—Dr. Walter A. Ver Wiebe, Mr. R. L. Belknap and Miss Ellen Stevenson.

MR. M. DIXON, of Emmanuel College, Cambridge, has been appointed senior demonstrator in biochemistry for five years.

DR. WILLIAM F. SHANKS, who graduated with special distinction in physiology in the University of Glasgow, has been appointed professor of physiology at the University of Leeds.

DISCUSSION AND CORRESPONDENCE

WATER GLASS AS A MOUNTING MEDIUM

IN your issue of July 6, page 13, "water glass" is recommended as a substitute for Canada balsam as a medium for mounting objects for microscopic study. In 1870 I experimented with this substance, which at first appeared satisfactory, but after some months a host of fine acicular crystals developed in it, finally obscuring and completely ruining the slides.

WM. H. DALL

U. S. NATIONAL MUSEUM

I HAVE not used water glass in the way described by Mr. Dean T. Burk, but have been using it for years as a cement for fossils, pure or mixed with chalk or plaster of Paris. At first I found it satisfactory, being clean, drying quickly and fixing well. But after two or three years the glass changed its constitution, becoming crystalline, and the pasted objects became loose, so that I ejected it at once from my laboratory at Petrograd and never used it again.

I suggest that the same crystallization, and surely with the same sad effect, must take place in the water glass when used as a mounting medium for microscopic objects. In any case, the experience of some years is necessary to approve this method.

The use of water glass as a substitute for shellac in mounting insects on points, is, in my opinion, for the reason given above, absolutely unacceptable. If such a substitute is looked for by entomologists, I would recommend them to try the solution of some celluloid in acetone, a composition that I have used for years very successfully as a cement for fossils. This solution is just as handy as water glass, but it has not the inconvenience of the latter and can be prepared of different consistencies, an important item in many cases.

The celluloid, remaining after the evaporation of acetone, pastes together very strongly, keeps its property practically forever and in comparison with shellac is nearly colorless, unaffected by heat and does not snap off.

T. TOLMACHOFF

CARNEGIE MUSEUM

IN connection with the article by Dean T. Burk, of the University of California, in SCIENCE for July 6, I wish to call attention to an article which I published in the *Journal of Applied Microscopy and Laboratory Methods*, just twenty years ago, the exact date being July, 1903. The method is given in detail, together with its advantages and disadvantages, and at that time had been in use by myself and associates for about two years.

There are several objections to the use of water glass for mounting histological and pathological sections, the main ones being its poor clearing power and its alkaline reaction, which would have a detrimental effect on many stains. The method is of value for certain unstained preparations, notably vegetable fibers, if only moderate durability is desired.

CHARLES E. M. FISCHER

THE FISCHER LABORATORIES, INC.

FILING REPRINTS

DR. W. G. FARLOW filed his reprints in very shallow, flat drawers, laying them face up, one in a place. I began by binding mine into fairly good sized volumes with an index. Afterwards, having to consult one number in a volume repeatedly, I became weary of handling the heavy book for the sake of a tiny separate and abandoned this method. Ten or fifteen years ago I adopted one similar to that described by Edwin G. Boring in SCIENCE, October 26, 1923, and have found it very convenient and satisfactory.

Apparently the only difference is that I buy my boxes by the 5-hundred from a box maker and have the sides cut beveling at the top so that the top width of the side is 2 inches and the bottom width is 7½ inches, the lower end of the bevel running out at a height of 4 inches from the bottom of the box. The height of the box is 11 inches, the width of it, outside measurement, 3 3/16 inches, giving an inside measurement of 3 inches. On the back of each one I paste a typewritten list of the authors inside, arranged alphabetically. I write at the top of each separate, on both the front and back, the name of the author, and the object of the bevel is now apparent because when the box is pulled out the upper back corner of the separate projects out of the box. By running them over with my fingers I can see in a moment, without looking at the titles, all I have by a given

author, and whichever way I grab up the box—front or back. It is so long since I have had any of these boxes made that I do not remember the cost and, of course, that would vary with the locality and material. The boxes I have are made of good grade pasteboard, about 3/32 inch thick, covered at back and joints with black cloth. The only objection to such open boxes is dust, but if they are shut into glass-faced, unit-size, extra high, bookcase sections, the glass front lifting to a horizontal position and sliding back over the boxes, the dust difficulty is not great. Tiers of these, one above the other, enable one to see at a glance all his separates on a given subject. The units I have are about 12 inches deep, 15 inches high and each one will hold 9 of these boxes. They are known as book-case sections, outside dimensions 33 inches wide, 13 inches deep and 16¾ inches high, fitted with disappearing glass panel door with non-binding device, and were purchased from the Globe-Wernicke Co.

ERWIN F. SMITH

GERMAN SCIENTIFIC MEN AND RESEARCH

IN these sad times of political and economic depression in Germany, it is worth while to note the interest that is still maintained in research among the German scientists. The writer attended the third annual congress of the *Deutsche Gesellschaft für Vererbungswissenschaft* which met in Munich from September 24 to 27 of the present year. The meetings, which were held in the anatomical institute of the university, were presided over by Richard von Hertwig and were attended by three hundred scientists. The program was divided into three sections for the reading of papers—the botanical papers coming on Monday, the zoological on Tuesday, and the anthropological on Wednesday. For Thursday, an excursion was planned into the Tyrol.

More important to the writer than the papers read was the fact that, in such times as these, university professors were willing to spend from their salaries (about two hundred and fifty dollars a year) a sum equal to one or two weeks' income, and this at a time when the railroad fares were to be increased two and a half times before their return home. The excursion into the Tyrol was announced as fourth class on the railroad and most of those present had traveled fourth class to Munich. Black bread without butter at home, board seats on the railroad, but genetics at Munich! About one fourth of those in attendance were women, and women took part in the discussion. Among those present were such well known men as Hertwig and Goebel, of Munich; Spemann, of Freiburg; Lehmann, of Tübingen; Oehlkers, of Heidelberg; Kniep, of Würzburg; Renner, of Jena; Winkler, of Hamburg; Goldschmidt and the younger von Wettstein, of Dahlem; Buder, of Griefswald, and the elder von Wettstein, of Vienna.

F. C. NEWCOMBE

STUTTGART, GERMANY

QUOTATIONS

MINERVALS

A CONTRIBUTOR to the current number of SCIENCE named Welsh, writing from Nirvana (not the state of beatific freedom from earthly ills, but Nirvana in the State of Pennsylvania), makes reply to an earlier contributor, Professor Preston Slosson, in the matter of the meager salary of Professor Blank as compared with the income of John Smith, merchant. Professor Slosson, as protagonist for Professor Blank, shows that his client's salary can never be more than $4,500 at 60, at which age he is retired on half pay—that is, less than $2,500; while John Smith, merchant, starting at 15 years of age as an office boy at a salary which Professor Blank does not have until he is 25, is at 60 enjoying profits of $25,000 a year as a retired stockholder, or ten times the income of Professor Blank. He holds that Professor Blank's salary ought to be at least $8,000 or $10,000. Otherwise the business world can always outbid the college for the services of able men. He contends that the leisure of the college man (which is supposed to justify a smaller money stipend) is a myth, and that while the pleasantness of his occupation is undeniable, if salaries were cut down on that account some of the wealthiest men should have a like cut, since they are "hardly happy" away from their offices and would enjoy a Latin professorship even less than a Latin professor would enjoy a seat in the Stock Exchange.

Moreover, while business has its millionaires, education has none. Its "minervals" are reckoned in thousands at most. Even the authors of text-books do not rise to great wealth. The economic value to society of the research scientist of the highest calibre may be many times that of the ablest banker or railroad president, and yet he may be enjoying but a small fraction of the latter's salary (witness Dr. Steinmetz's insignificant savings of a lifetime). It would be only a fitting recognition to pay these outstanding men of science as much at least as a first-class "realtor."

Comes now Mr. Welsh, of Nirvana, and says that John Smith, merchant, is far beyond the average merchant in his income; that of those who attempt business for themselves 90 per cent. are failures and are forced to drop out with their capital completely used up; that those who succeed are the most severely selected class in the world; that the average professors should be compared not with the successful business man but with his employes, and that they get

"all they are worth to the community." He even goes so far as to assert that few of these "audible books," as he calls them, benefit the community so much as the average clerk, because "their efforts are not directed and coordinated" as are those of the clerks.

Without disparagement of merchant or clerk, it is to be remembered that it is largely by the guidance of those who perform such service as that of Professor Blank that we progress toward the true state of Nirvana on earth. If the real value of these teachers and researchers were estimated by what America would conceivably be without their intangible, spiritual contributions, not to mention what their discoveries have added to life's comfort, convenience, length and strength, their wages would be incalculably augmented. If for "Professor Blank" were written, for example, "Professor Joseph Henry," is there any salary that would be quite adequate to pay civilization's debt to this Albany schoolmaster and Princeton professor? The tinkle of the tiny bell that he first rang by electricity is soon to be heard by radio around the world. But the influence of many a professor is felt as widely. His merchandise is "better than silver." His "minervals," as his wisdom fees were called in ancient times, should, however, be sufficient to permit him to remain where he can give the highest service to the community.—*The New York Times.*

SCIENTIFIC BOOKS

Labyrinth and Equilibrium. Monographs on Experimental Biology. By S. S. MAXWELL. 163 pp., Philadelphia and London: Lippincott, 1923.

IT should be sufficient, for the purposes of most reviews, to be able to say that the book had been written by one who had actually worked at the problems discussed and who had contributed many illuminating facts in a subject which has been obscure since the first pioneer entered the field. I can say this of the volume now under discussion. The author's own work, so lucidly described in the pages of this book, has given us a clearer idea than we have had of the mechanism of stimulation of the afferent nerve endings in the non-auditory portion of the internal ear.

Goltz stated the general problem of the function of the non-auditory or vestibular portion of the internal ear nearly two generations ago. Three things are necessary: (a) The peripheral receptor and the afferent nerve; (b) the central nervous system, and, (c) the efferent nerves, together with their effectors—the skeletal and various other muscles in the case of the present mechanism. The book deals, for the most part, (a) with the relation of the labyrinth to forced or abnormal positions of the organism, and to the compensatory positions which follow the displacement of the animal from its normal position and, (b) with the general mechanism of stimulation of the vestibular endings. These phases of the subject are handled with all the clearness which our present knowledge of the subject permits.

The final chapter is on nystagmus, the pecular ocular movements resulting from vestibular stimulation; the slow movement in one direction, say to the right, and a quick movement in the opposite direction. Nystagmus is due to some mechanism or mechanisms in the central nervous system—the second part of the problem as Goltz formulated it—and it should not be considered as a reflection upon the book to say that here the author's hand is a little less sure. Nor is it to be taken as a sign that the author is wrong when I say that he does not wholly accept some of the opinions of the reviewer. The problem of the functional organization of the nervous system is one of the most complicated and perplexing which the biologist has to face, and no one has yet given a clear and intelligible statement of the organization of the whole mechanism for the performance of any single function, nystagmus included. This should be a sufficient apology for any lack of certainty of conclusions in the author's final chapter.

Although it is not my purpose to review it here, I wish to mention another recent volume on the vestibule, written by a psychologist.[1] Maxwell's volume deals principally with the purely objective side of vestibular stimulation. Griffith deals with the subjective or psychological side of some common vestibular effects. In addition to giving the most complete bibliography of the subject of which I am aware, he has some remarks upon some common opinions of vestibular phenomena upon which neither fact nor argument has as yet made much impression.

F. H. PIKE
COLUMBIA UNIVERSITY

SPECIAL ARTICLES

A NEW PHOTO-ELECTRIC EFFECT

REFLECTION OF ELECTRONS INDUCED BY LIGHT

A STUDY of some vacuum tubes containing caesium vapor has shown a peculiar photo-electric effect. The action of white light on an adsorbed film of caesium on nickel seems to cause this surface to reflect elastically electrons which are made to impinge on it. The number of electrons that can be thus reflected is proportional to the intensity of the light.

Two nickel cylinders, B and C, open at the ends, were mounted end to end along the same axis, being but slightly separated from one another. Inside of

1 Griffith, Coleman R.: "An historical survey of vestibular equilibration," pp. 178. University of Illinois Bulletin, XX, No. 5, 1922.

cylinder B was a small tungsten filament A, used as a source of "primary" electrons. The tube containing these electrodes was exhausted to a high vacuum and some caesium was distilled into it before sealing off. Because of the adsorbed film of caesium on the tungsten, electron currents of convenient magnitude (50 micro-amperes) could be obtained at filament temperatures below a red heat (Langmuir and Kingdon, SCIENCE, *57*, 58 (1923)).

By placing a 200-watt Mazda lamp near the tube, so that some light entered the open end of cylinder C, photo-electric effects of two kinds were observed. The *first* was the *normal* photo-electric effect due to an adsorbed film of caesium on the cylinders. If either cylinder was made 40 volts or more negative with respect to the other, a current of electrons of a fraction of a micro-ampere passed from the negative to the positive cylinder under the influence of the light. By varying the voltage on the lamp it was found that this photo-electric current was proportional to the intensity of the yellow component of the white light (6000 A°). The photo-electric current was only cut down to about 1/10th by interposing a piece of deep red glass.

The *second* effect produced by light was observed only when B and C were both at positive potentials with respect to A and the filament A was heated sufficiently to emit electrons. The effect was manifested by an electron current flowing to C (through the space) which could not be accounted for by the normal photo-electric effect and which continued to flow to C even when the potential of B was much higher than that of C.

TYPICAL PHOTO-REFLECTION DATA

Tube at Room Temperature

E_C=100 volts E_B=60 volts I_A=21.8 microamperes

Volts on Lamp	Light Intensity	Current to C micro-amperes	Normal Photo Effect micro-amperes	Photo Reflection micro-amperes
V_L	L	I_C	I_N	Δ
0	0	0.14	0.000	0.00
40	5	0.18	0.000	0.04
50	18	0.28	0.001	0.14
60	50	0.52	0.002	0.38
70	98	0.87	0.005	0.72
80	172	1.21	0.010	1.06
90	266	1.26	0.016	1.104
100	385	1.28	0.024	1.116
110	540	1.30	0.037	1.123
120	730	1.32	0.055	1.125
130	960	1.36	0.103	1.12
140	1200	1.39	0.130	1.12

Typical data illustrating this effect are given in the table. The cylinders B and C were maintained at potentials of 60 and 100 volts respectively, these being measured from the filament A. This filament was heated to such a temperature that the emission from it was 21.8 micro-amperes.

Since this total emission was always uninfluenced by the amount of light entering the tube, the observed effect is not due to any variation in the electron emission from the filament. The light, however, did cause a change in the distribution of the current between the two cylinders, as indicated by the data in the third column, which gives the current to the cylinder C. In the absence of light a current of only 0.14 micro-amperes of electrons flowed to C, while the remainder flowed to B. This small current to C was, however, due to electrons reflected from the surface of B rather than electrons coming directly from the filament.

The first column gives the voltage applied to the Mazda lamp whose rated voltage was 120. The second column gives in arbitrary units the relative light intensity of wave length 5300 A°, calculated from the filament temperature by Wien's law for radiation.

It is seen that the current to C increased with the intensity of illumination at first rapidly, but then approached a nearly constant limit. A part of this current, however, is due to normal photo-electric current. Column 4 gives the current I_N to the electrode C, due to this normal effect. This was observed by lowering the filament temperature to any point lower than that at which it ceased emitting electrons.

Column 5 contains the quantity $\Delta = I_C - 0.14 - I_N$, which is that part of the *increase in current to C which is caused by light and which can not be accounted for as a normal photo-electric effect.*

This increase in current Δ varies at first in proportion to the light intensity L, but then becomes constant while the light intensity increases from 385 to 1200.

A large number of such runs were made with this tube, varying such factors as the voltages on B and C, the temperature of A, and the bulb temperature, and, therefore, the vapor pressure of caesium. The effect of transverse and longitudinal magnetic fields was also studied.

The results indicated that *below a certain light intensity,* which, however, varied with the conditions, *the quantity Δ is proportional to L, and in this range the ratio of Δ to L is entirely independent of the voltages on B and C, the electron emission from the filament, the bulb temperature or the presence of a magnetic field.*

On the other hand, with light intensities *above a certain limit* (not much greater than the limit previously referred to), *the quantity Δ is independent of L, but depends on each of the factors already enumerated.*

Thus by plotting Δ against L a family of curves is obtained which has as an envelope a straight line passing through the origin. If the light intensity is kept constant and the electron emission from A is increased from 0 to a large value, Δ increases at first with the emission (with the 1.6*th* power of it in one set of experiments) and then becomes constant when Δ/L has reached its limiting value.

These relationships are in many ways analogous to those in electron tubes where the current is in general limited either by emission from the cathode or by space charge, depending upon which limit has the lower value. Similarly, we may assume that the photo-electric reflection may be limited either by the number of electrons that strike the electrode, or by the amount of light reaching the electrode.

Although all the characteristics of this effect are not yet understood, it seems safe to assume that the effect is caused by an activation of an adsorbed caesium film by light, the atoms in this film being brought to such a state that they cause the impinging electrons to make elastic collisions.

The effect disappears if the voltage of either B or C is brought to zero. When the voltage E_C is less than E_B the normal photo-electric effect reverses in direction, but Δ does not do so. The limiting value of Δ for sufficiently high values of L, which we may call Δ_L, is greatest when E_C is considerably larger than E_B. Thus with $E_C = 100$, $E_B = 60$, and $I_A = 26$, Δ_L had a value 2.9, while for $E_C = 20$, $E_A = 100$, and $I_A = 47$, Δ_L was 0.07. The fact that the effect still existed under the latter conditions proves that several per cent. of the electrons which are reflected from B lose not more than 20 per cent. of their energy.

With E_B kept at 20 volts, Δ_L was 1.4 for $E_C = 20$, and it steadily increased as E_C was lowered below this point, until, at $E = 5$ volts, there was a sharp maximum ($\Delta_L = 3.3$). Another even greater maximum of $\Delta_L = 4.2$ occurred at $E_C = 1.1$ volt. At $E_C = 0.5$ volt the effect fell abruptly to zero.

A sharp distinction between the new photo effect, measured by Δ, and the normal effect I_N, is that the new effect disappears entirely if a piece of red glass is interposed in front of the light source, Δ falling at least to 1/1000th of its original value, whereas the normal effect decreases only to about one tenth. It is probable that the effect is mainly due to light having a wave length of about 5300 A° (blue-green).

A similar activation of a nickel surface causing electron reflection has also been found in connection with some measurements of the distribution of velocities of electrons in the positive column of the mercury arc, by a method like that described recently for measuring positive ion currents. (Langmuir, SCIENCE, *58*, 290 (1923)). By introducing high speed electrons (40 volts) into the mercury arc by means of a heated negatively charged tungsten filament, it was found that the ability of a small collecting electrode (1 sq. cm area) to take up low speed electrons was greatly impaired.

IRVING LANGMUIR

RESEARCH LABORATORY,
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THE ABNORMAL REFLECTION OF X-RAYS BY CRYSTALS

IN recent papers[1] we have described experiments which show that under certain conditions a crystal of potassium iodide deflects x-rays in a way that does not obey the ordinary laws of x-ray reflection. The discovery and extensive study of these abnormal reflections, called x-peaks, were made by means of ionization spectrometers. A number of experiments demonstrated that the x-peak reflections vanished when the voltage fell below the critical voltage required to produce the K series lines of iodine. From this we conclude that the abnormally reflected rays consisted of the characteristic line spectrum excited by the primary x-radiation in the iodine atoms of the reflecting crystal itself. The angle of reflection from the crystal depended in a complicated way upon the angle of incidence of the primary rays, and the phenomenon can not be regarded as ordinary reflection from any single set of crystal planes. We took special care to prevent rays regularly reflected by the various sets of planes from entering the ionization chamber.

We published in the *Journal* of the Optical Society (*l.c.*) the reproduction of a photograph taken in such a way as to show the x-rays defracted by the crystal of potassium iodide. The primary x-rays in this case passed through the crystal parallel to an axis. Four spots, in addition to that due to the direct beam of x-rays, appeared on the photograph in positions corresponding with the data obtained for the x-peaks by the ionization spectrometer. Thus the existence of the x-peak reflection was confirmed by the photographic method.

A letter from the Geophysical Laboratory has appeared in SCIENCE recently (July 20, p. 52) written by Mr. R. W. G. Wyckoff, in which he briefly describes experiments with a potassium iodide crystal and a photographic plate. The very excellent copies of these photographs, which he has been kind enough to send us, show no spots that can be attributed to the abnormal x-peak reflection. We thought it best to delay comment on this letter until we could make

1 *Proc.* Nat. Acad. Sci., 8, 90 (1922); 9, 131 (1923); *Jour.* Optical Soc., 7, 455 (1923).

an effort to ascertain what the important differences really are between Wyckoff's experiments and our own. This we have not been able to do until very recently, because we did not wish to interrupt other researches already in progress.

We have reinvestigated the x-peak phenomenon both with the ionization spectrometer and by means of photographs, and the results completely confirm our previous conclusions. At least one of these photographs with a detailed description of the apparatus will be sent for publication in a future paper. The photographs show a large number of Laue spots reflected in the ordinary way from the various crystal planes together with the four well-defined spots that can not be reflected from any conceivable planes in the crystal and which correspond exactly in position with the x-peak reflections. On one of these photographs no spots except the central image are more strongly marked than those representing the x-peak reflections. There can be no doubt as to the reality of these abnormal reflections of the rays by the potassium iodide crystal.

Mr. Wyckoff's experiments are similar to the original experiments of Laue, Freidrich and Knipping, performed eleven years ago. These have been repeated over and over again by many scientists. It is not likely that such experiments would bring out the abnormal x-peak reflections in any reasonable length of time, for, if they did, the abnormal reflections probably would have been discovered long ago. The first experiments that we, ourselves, performed with photographic plates were more or less of the same kind, and in these we did not get evidence for the x-peak reflection. It was only by modifying the experiments that we succeeded in getting this photographic evidence after many hours of exposure.

As the x-rays deflected by the crystal can be detected and measured easily in a few seconds of time by their ionizing effects, this indicates the very great analyzing power of the ionization method as compared with the photographic for certain purposes.

The important differences between our experiments and the ordinary Laue photographic experiments appear to be as follows:

(*a*) Mr. Wyckoff applied to the x-ray tube an alternating voltage with a peak value of approximately 50,000 volts. It required at least 33,000 volts to produce the characteristic radiation of iodine. In our experiments we employed a voltage of 75,000 volts, more than twice as far above the critical voltage of iodine as that used by Wyckoff. Further, our voltage was constant, and did not fluctuate with the time. The fact that the voltage remained at 75,000 all the time means that our primary x-ray beam was far richer in short x-rays, the kind of rays that produce the iodine line spectrum most effectively, than was the alternating voltage employed by Wyckoff. The difference in power of producing the characteristic radiation of iodine between a constant voltage of 75,000 volts and an alternating voltage of 50,000 volts is very great.

(*b*) In the experiment which gave us our best photographs we used a single pin hole in a lead sheet to define the beam of x-rays incident on the crystal. Thus, the cross-section of this beam was determined by the area of the pin hole and that of the focal spot on the target of the x-ray tube. Further, the target of the x-ray tube was so placed that the rays passing through the pin hole almost grazed the target's surface on leaving it. This arrangement greatly increases the intensity of the x-radiation passing through a small opening. We have also made experiments with two pin holes to define the incident beam, the arrangement ordinarily used in taking Laue photographs and the arrangement which Mr. Wyckoff employed. We found that the intensities of all the spots on the photographic plate were somewhat reduced by inserting this second sheet of lead with a pin hole in it, but the intensities of the spots representing the x-peak radiation were reduced in a very much greater ratio than the others, so that employing two pin holes to define the beam decreases the photographic effect of the x-peak radiation as compared with that of the ordinary reflection. This phenomenon is quite marked. It undoubtedly is due to the fact which we have mentioned several times, namely, that the characteristic reflection of x-rays is not as accurate a phenomenon as the ordinary reflection of x-rays. In the case of the ordinary reflection only those rays of given wave-length that are practically parallel to a given line are reflected by a given set of planes. In the case of the reflection of the characteristic rays, the direction of the incident beam does not have to be so accurately parallel to the given line.

(*c*) We used a somewhat thicker crystal of potassium iodide than that employed by Wyckoff. As the characteristic wave-lengths of iodine lie in the portion of the spectrum for which iodine is most transparent, this means that our crystal let through a larger proportion of characteristic rays as compared with other rays than was the case in Mr. Wyckoff's experiments.

As stated in our papers, we have observed other anomalous deflections of x-rays by a crystal much weaker than the x-peak reflections. Dickinson[2] has recently detected similar anomalous deflections by the photographic method. He explains his results by assuming that they are due to reflections by "small crystals individually perfect but with their axes slightly inclined to those of the main crystal." This hypothesis does not explain the strong x-peak reflec-

[2] *Physical Review*, Aug., 1923, p. 199.

tions, for one can not deduce from it the observed characteristics of the x-peak phenomena—such, for instance, as the way in which the angle of reflection depends upon the angle of incidence of the primary beam, the appearance of only one x-peak in each quadrant and the fact that the critical voltage is always about equal to that of the K series of iodine. The influence of the critical absorption of the chemical elements in the crystal has been indicated on many of our published diagrams.

It is evident from the above-mentioned experiments that all the possible reflections of x-rays by a crystal such as potassium iodide have not yet been thoroughly examined. The possibility of abnormal reflections has a direct bearing upon the analysis of crystals by means of x-rays, especially upon those methods of analysis which require the taking of Laue photographs. For a completely satisfactory analysis of crystals by such a method it would be necessary to determine what the wave-length of the various deflected beams are. Probably no mistakes would be made in analyzing crystals of simple forms, such as cubic crystals, but in the more complicated cases the fact that abnormal reflections occur must always be borne in mind and in case of doubt the wave-lengths of the deflected beams should be determined. It would be difficult to measure the critical voltages for these deflected rays by the photographic method, but they could be easily determined by an ionization spectrometer.

HARVARD UNIVERSITY

GEORGE L. CLARK
WILLIAM DUANE

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

MEETING OF THE EXECUTIVE COMMITTEE

THE meeting was called to order in the board room of the Cosmos Club, Washington, at three o'clock on the afternoon of October 14 with the following members present: Cattell, Fairchild, Howard, Humphreys, Livingston, Osborn, Walcott, Ward. The following were absent: Flexner, MacDougal, Noyes. President Walcott was elected chairman. The minutes of the last meeting were approved as previously circulated. The following interim minute of action by mail was approved: September 17, 1923. On nomination of the section committee of Section M, Mr. John T. Faig was elected to be vice-president for Section M and chairman of the section for the current year.

The permanent secretary's report on the affairs of the association was presented in mimeographed form, and was accepted. The permanent secretary's annual financial report (of September 30, 1923) was presented and accepted, and it was ordered to be audited and presented to the council at the next annual meeting.

The treasurer's report was presented by Mr. John L. Wirt, who was present by invitation. It was accepted and ordered to be audited and brought before the council at the next annual meeting.

An appropriation of $4,500 was voted for grants, including the recent Newcomb Cleveland gift of $500.

The permanent secretary reported that the project of starting a quarterly publication, to include the preliminary announcement of the annual meeting, has been postponed for the present on account of uncertainty as to funds.

The permanent secretary reported that the special committee on the philological sciences is active and that a program on this subject will be presented at the approaching Cincinnati meeting.

The appointment of Dr. Charles A. Shull, of the University of Chicago, to be assistant secretary of the association in the place of Dr. Sam F. Trelease, resigned, was approved. This appointment is for the period from September 1, 1923, to the end of the Cincinnati meeting.

The sponsorship, by the association, of the project on the standardization of engineering and scientific abbreviations and symbols was approved. The association becomes sponsor, along with the U. S. Bureau of Standards and the Society for the Promotion of Engineering Education, for the preparation of a system of standardized symbols, etc., without any financial obligations on the part of the association. The association reserves the right to pass upon the recommendations of the joint committee, when finally made, and, for its own part, to approve or disapprove, in whole or in part. The special committee which represents the association in this work consists of Dr. Henry N. Russell, of Princeton University, chairman; Dr. Augustus Trowbridge, of Princeton University, and Dr. E. W. Washburn, of the National Research Council.

The question of further publicity for the resolution on Pueblo Indian lands (adopted April 22, 1923) was left to the general and permanent secretaries, with power. The resolution has been widely published and a supply of printed copies is available at the permanent secretary's office.

One hundred and twenty-six fellows were elected, distributed among the sections as follows: Section D, 1; Section M, 12; Section O, 112; Section Q, 1.

It was voted that the permanent secretary call a meeting of the executive committee on the evening of Wednesday, December 26, at Cincinnati, if, in his judgment, there are matters for consideration that may not be cared for satisfactorily at the forenoon meeting on the following day.

After the reading of communications from the

British Association for the Advancement of Science, which evidenced the approval of that association, it was voted that the American Association for the Advancement of Science shall hold a summer meeting at Buffalo, preceding the Toronto meeting of the British Association to be held in September, 1924.

The following resolutions were adopted, regarding the permanent endowment of the association and the income therefrom:

(1) *Resolved:* That an assistant treasurer of the association be appointed, to serve till the end of the next Washington meeting, whose duties shall be to assist the treasurer.

(2) *Resolved:* That checks drawn upon the authorized account of the association in the Fifth Avenue Bank, of New York, be signed by the treasurer or assistant treasurer and countersigned by the president or the permanent secretary of the association.

(3) *Resolved:* That the treasurer or assistant treasurer be authorized to open an account with the American Security and Trust Company, of Washington, in the name of the American Association for the Advancement of Science with instructions that checks on this account be signed by the treasurer or the assistant treasurer and countersigned by the president of the association or the permanent secretary.

(4) *Resolved:* That the Finance Committee shall consist of the treasurer and assistant treasurer and three members to be elected by the Executive Committee, one each year for a term of three years.

(5) *Resolved:* That the Finance Committee shall have custody of the securities of the association and general charge of its investments and invested funds, with power to sell and deliver any securities belonging to the association whenever occasion may arise to do so; and the president and treasurer, or assistant treasurer, of the association are authorized, with the approval of said committee, to execute any necessary instrument or instruments of transfer and to affix the corporate seal of the association thereto.

(6) *Resolved:* That all moneys appropriated for use under allotments to be made by the Committee on Grants and not used during the calendar year for which the appropriation has been made, shall revert to the treasury at the end of that calendar year. (Appropriations are generally made at the annual meeting, at the beginning of the calendar year. Allotments are made by the Committee on Grants, and disbursements are made by the treasurer's office in accordance with directions from the Committee on Grants. If an allotment be made and accepted by the grantee and the latter wishes not to draw the funds—or to draw only part of them—within the calendar year for which the appropriation was made, such an allotment is to be considered as used within the calendar year. When a grant is not accepted or is returned by the grantee, the Committee on Grants may re-allot it to another grantee, as of the same calendar year, but no funds appropriated for use under allotments by the Committee on Grants during any year and not accepted by the grantees during that year are to be available for allotment and disbursal in the succeeding year unless again appropriated for the latter year.)

In accordance with resolution 1, above, Mr. John L. Wirt was elected assistant treasurer of the association, his term of office to expire at the close of the Washington meeting of 1924.

The executive committee voted that the permanent secretary write a note of sympathy and condolence to Mrs. R. S. Woodward, on account of the protracted illness of Dr. Woodward.

It was voted that the annual meeting for 1926 shall be held at Philadelphia, the dates being, according to the adopted schedule, from Monday, December 27, 1926, to Saturday, January 1, 1927. Future annual meetings thus far decided on are as follows:

1924, Cincinnati: Thursday, December 27, 1923, to Wednesday, January 2, 1924.
1925, Washington: Monday, December 29, 1924, to Saturday, January 3, 1925.
1926, Kansas City: Monday, December 28, 1925, to Saturday, January 2, 1926.
1927, Philadelphia: Monday, December 27, 1926, to Saturday, January 1, 1927.
1928, ————————: Monday, December 26, 1927, to Saturday, December 31, 1927.
1929, New York: Thursday, December 27, 1928, to Wednesday, January 3, 1929.

A request for exchange of publications was received from the Staats- und Universitätsbibliothek of Hamburg, and the permanent secretary was authorized to send to that library the Proceedings volumes.

A communication (October 10) and an offer were received from a member of the association, concerning the awarding of a prize for scientific achievement in 1924, and the offer was accepted with thanks. The donor is to remain unnamed. A special committee was appointed to consider and provide arrangements for carrying out the terms of the offer. This committee consists of the president, the permanent secretary, and Dr. Cattell, the last being chairman.

It was decided that the section secretaries be invited to be the guests of the association, to meet the members of the executive committee, at a dinner to occur on Sunday evening, December 30, at Cincinnati, the dinner to be preceded and followed by conferences on the affairs of the association.

It was voted that the Saturday evening session at Cincinnati (December 31, 1923) shall be devoted to a series of brief talks by past presidents of the association and the permanent secretary was instructed to invite all living past presidents to take part. This session is planned specially in celebration of the seventy-fifth anniversary of the founding of the association.

It was voted that the collection of photographs of